9. *On the* Relation *of the* Westleton Beds, *or* Pebbly Sands *of* Suffolk, *to those of* Norfolk, *and on their* Extension Inland; *with some* Observations *on the* Period *of the* Final Elevation *and* Denudation *of the* Weald *and of the* Thames Valley, *&c.* By Joseph Prestwich, M.A., D.C.L., F.R.S., F.G.S., &c. (Read December 18, 1889.)

PART II.

[Plate VII.; see also the Map in Part III.]

Page
1. Classificatory Objects and Historical Summary 120
2. Range inland of the Westleton Beds north of the Thames: Suffolk (p. 124); Essex (p. 128); Middlesex (p. 136); Hertfordshire (p. 137); South Buckinghamshire (p. 139); South Oxfordshire (p. 140); Berkshire (p. 141) 124
3. Westleton Beds on the South of the Thames: Kent; Surrey and Hampshire 143
4. Possible extension of the Westleton Shingle beyond the Thames Basin into Wiltshire and Somerset 143
5. Relation of the Westleton Shingle to the Glacial Drifts of the Thames Valley 144
6. Origin of the Shingle 145
7. Conclusion—Elevation of the Westleton sea-floor; Formation of the Gorge of the Thames at Goring; Measures of Glacial and Post-Glacial Denudation. Age of the Chalk and Oolitic Escarpments... 148

1. *Objects of the Paper &c.*

In the first part of this paper * the relation of the Westleton Beds in the Eastern Counties to the Crag Series on the one hand, and to the Glacial Series on the other, was discussed. My object in this part is to trace the extension of the former beyond the area of the Crag, and to show that a Westleton Shingle-bed passes transgressively over the Red Crag, the Tertiary strata, and the Chalk, and ranges westward through the length of the London Basin, while it rises to considerable heights above the Glacial Drifts and exists independently of them; and although it occupies only isolated and detached outliers, if the relation of these outliers to the Pre-Glacial Beds of Suffolk and Norfolk—the position of which has been proved—can be determined, we shall then have a definite base by which to correlate them and establish the order of succession and relative age of the many Drift Beds of the London Basin.

I purpose therefore to proceed step by step and to take each stage separately, confining myself now to the oldest and highest stage, where the distinctive characters of composition are best defined.

* Quart. Journ. Geol. Soc. for February 1890, p. 84.

E

Bures. Westleton. Southwold.

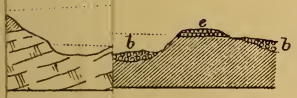
60.

a _ Post glacial Drift (site of)
b Boulder Clay and Gravel.
c Westleton Beds.
d Southern Drift.
e Brentwood Shingle.
1 _ Crag and Chillesford Beds.
2 _ Tertiary Strata.
3 _ Chalk.
4 _ Upper Greensand & Gault.
5 _ Lower Greensand.
6 _ Wealden.

N N

Hatfield. Writtle Park.

200. 310.



—— Scale. ——
Vertical — $\frac{1}{10}$ inch = 100 feet.
Horizontal _ 1" inch = 5½ miles.

MARKS

A _ Boulder Clay.
A' _ Boulder Clay Gravel.
B _ Westleton Beds.
C _ Crag Beds.
D _ Bagshot Sands.
E _ London Clay.

Vertical Scale
1 inch = 60 feet

Prof.ᵇ J. [illegible]

Diagram-Sections of the Pre-Glacial Hill-Drifts of the Thames Basin.

Quart. Journ. Geol. Soc. Vol. XLVI. Pl. VII.

Fig. I. Section from Oxfordshire to the Coast of Suffolk.

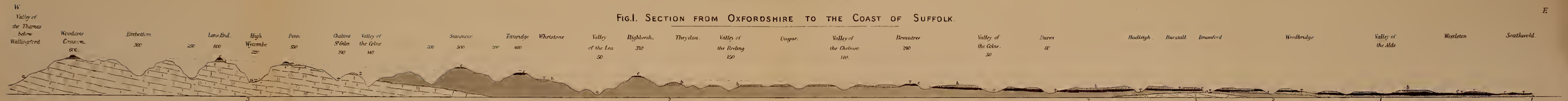


Fig. 2. Section from Surrey to Buckinghamshire.

Fig. 3. Section from Surrey to Hertfordshire.

Fig. 4. Section from Kent to Essex.

a. Post glacial Drift, site of
b. Boulder Clay and Gravel.
c. Westleton Beds.
d. Southern Drift.
e. Brentwood Shingle.
1. Crag and Chillesford Beds.
2. Tertiary Strata.
3. Chalk.
4. Upper Greensand & Gault.
5. Lower Greensand.
6. Wealden.

Scale.
Vertical 5 inch = 100 feet.
Horizontal 1 inch = 5½ miles

Fig. 5. Railway Cutting, Brentwood.

Fig. 6. Railway Cutting, Black Notley near Braintree.

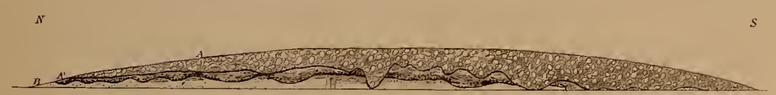
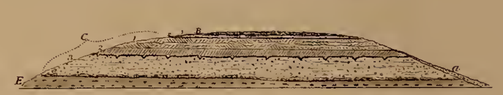


Fig. 7. Railway Cutting between Chapple and Marks Tey.

Fig. 8. Railway Cutting, Kyson near Woodbridge.



A. Boulder Clay
A'. Boulder Clay Gravel.
B. Westleton Beds.
C. Crag Beds.
D. Bagshot Sands.
E. London Clay.

Vertical Scale
1 inch = 60 Feet

These are lost in later stages, owing to frequent reconstruction, but we can then follow by levels.

In 1847 * I showed that in the neighbourhood of London there were hill-gravels as distinct from valley-gravels, but I was not then in possession of any clue whereby to fix their separate age. Subsequent observations, especially aided by the cuttings on the Great Eastern Railway then in course of construction, enabled me to follow the Pre-Glacial Beds of Suffolk in their inland range, and to recognize their higher position in relation to the Drifts of the Thames Valley.

In my paper of 1871 on the Westleton Beds † I briefly alluded to their extension into the Thames Valley area, but reserved the details for subsequent description. Other occupations and the need for verification of some of my early observations led to a long delay in publication, though in 1881 ‡ I gave a short preliminary notice of some of the hill-drifts in the London Basin—such as those at Highbeech, Barnet, Southgate, Hertford, Hatfield, South Mimms, St. Albans, Tiler's Hill, Horsington, and Bowsey Hill §—which are capped by Drift Beds of Westleton age. I now purpose giving these in detail, and I only regret that owing to the lapse of time many of the sections I have to describe are no longer visible. The delay, however, gives me the advantage of the observations recorded by other geologists, and especially by Mr. Whitaker and other officers of the Geological Survey, and also enables me to avail myself of the heights and contours given in the last published sheets of the 1-inch Ordnance Survey, so indispensable in an inquiry of this description, and for which I had previously to depend on the observations I had made with an aneroid barometer ‖.

In 1864, Mr. Whitaker, in his account of the Post-Pliocene Series ¶ of parts of Middlesex, Hertfordshire, Buckinghamshire, Berkshire, and Surrey, alludes to the occurrence of a "gravel wholly or for the greater part made up of flint pebbles" on the tops of various hills in Hertfordshire and Buckinghamshire.

In 1877 he stated that there were two gravels in East Essex**,

* 'The Ground Beneath us,' p. 30.

† Quart. Journ. Geol. Soc. vol. xxvii. p. 477.

‡ Reports Brit. Assoc. p. 420. I was not then acquainted with Mr. Whitaker's latest Memoir.

§ Other hills were named, but these relate to the Southern Drift, which I now take separately.

‖ I regret also that I find it impossible to revisit, as I had intended, the many localities described, in order to check and revise my early observations, the greater number of which were made before my views were matured. Consequently, there may be inaccuracies which have escaped me, or analogies which I may have overlooked. I could also have wished to have given greater certainty to the percentage values of the Westleton and Southern Drifts—a plan which only occurred to me after much of the work had been done. I fear I may have overestimated the relative proportions of some of the essential constituent materials, but not to such an extent as to vitiate the general argument, while the facts, I trust, are recorded with sufficent accuracy to justify the conclusions at which I have arrived.

¶ Mem. Geol. Survey, Expl. Sheet 7, p. 69 (1864).

** "On the Geology of the Eastern End of Essex (Walton-on-Naze and Harwich)," Expl. of Sheet 48 S.E. p. 16.

one of which he considered to be of Glacial age, and the other Post-Glacial; and in the following year he noticed a small deposit of pebble-gravel capping the hills near Hertford *, which he thought might "be of Pre-Glacial age, but all that is known of it with absolute certainty is that it is older than the Boulder Clay (which occurs over it in other parts), and Mr. S. V. Wood, Jun., has classed it with his 'Middle Glacial.'"

In 1875, and again in 1880, Mr. Whitaker noticed in more detail † this "Pre-Glacial (?) Pebble-Gravel," and assigns to it more definite limits. He says, "On the tops of the London-Clay hills there is often a mass of sandy gravel of an exceptional sort, that is to say, it is almost wholly wanting in the more or less angular pieces of flint that form the greater part of the other gravels to be described, and, like the far older gravel-beds of the Blackheath and Bagshot Series, its component stones have been rounded into the form of pebbles. Showing at first sight a very great likeness to these old Tertiary pebble-beds, after a more careful examination this gravel is seen to be easily distinguished from them; for whilst the former are made up of flint-pebbles, that is not the case with the latter, which contains also a large proportion of pebbles of quartz and quartzite, and here and there a sub-angular flint." "The flint-pebbles have probably been derived from the destruction of the old Tertiary pebble-beds; but the pebbles of quartz, quartzite, and other older rocks that occasionally occur must have been derived from beds that are not found anywhere in our district.

"Of the age of this gravel we cannot yet speak with certainty. It is newer than the Lower Bagshot Beds, for it is known to overlie them; and it is older than the Boulder Clay, which is found above it, but between these extremes we are left to reason by analogy and by the evidence given by the manner of its occurrence."

"From its occurrence on the tops of the hills, whilst the Middle Glacial gravel often lies at their base, or on their flanks, it would seem that the pebble-gravel is the older of the two and was deposited long before those hills were cut into their present form, a process which must have been somewhat advanced before the other gravel was laid down. It is possible, therefore, that the pebble-gravel may represent some part of the 'Lower Glacial Drift' (of Mr. Wood), any known occurrence of which is, however, as far distant as the Crag."

"The chief localities are Stanmore Heath from Shenley south-eastward, west and north of Barnet, and at Totteridge, in Middlesex; at Highbeech, Jacks Hill, and Gayne's Park, east of Epping, in Essex, and at Shooter's Hill, in Kent."

In the larger valuable memoir ‡, published since these pages were written, Mr. Whitaker describes these Beds, which he places with

* "The Geology of the N.W. part of Essex and the N.E. part of Herts," Mem. Geol. Survey, Expl. of Sheet 47, 1878, p. 32.

† "Guide to the Geology of London and the Neighbourhood," Mem. Geol. Survey (1st edit. pp. 49–51, and 3rd edit. pp. 54–57).

‡ 'Geology of London,' vol. i. pp. 290–298 (1889).

"Doubtful Deposits," in greater detail and with some slight changes, and retains the open term of "Pebbly Gravel."

In 1867 * Mr. Searles V. Wood, Junr., called attention to the relations between the Post-Glacial, Middle, and Upper Glacial deposits of the Valley of the Thames, in connexion with the position of the latter two on the hills and in the valleys of this area. Prof. Boyd Dawkins showed, however, that his contention—based on theoretical grounds, that certain valleys "could have had no existence at the period of the Glacial Clay"—was not in accordance with the Survey observations.

In 1868 † Prof. T. M'K. Hughes described an outlier of peculiar gravel he had noticed near Hertford, under the term of "Gravel of the Upper Plain" in contradistinction to the "Gravel of the Lower Plain." The latter he referred to the Glacial Series. Of the other he says, "From their great extent, persistent character, and uniform level, I think these gravels of the Higher Plain must be a marine deposit; but without a careful examination of the old coast-line, and of their behaviour as they approach the Crag country, I should not like to give any opinion as to their age." He further states that they were of great antiquity and older than the Boulder-clay.

Mr. Wood, commenting on this communication, contended that this Gravel of the Upper Plain was of an age intermediate between his "Middle Glacial" and the Boulder-clay; while the outliers of other pebbly gravels at Brentwood, Highbeech, South Weald, Langdon Hill, and others ‡, were "not improbably of Eocene age."

Another paper of Mr. Wood's on the Wealden Denudation §, only bears incidentally on this question, as showing the existence and extent of Drift Beds in the Thames Valley older than the lower-level Valley-gravels.

The most important contributions to this subject by Mr. Wood are, however, those in which he sums up his numerous and extensive observations, and gives his final views on this and collateral questions ‖, accompanied by a map of the area occupied by the Chalky Boulder-clay, and a Plate of Sections showing the range and distribution of the Pre-Glacial, Glacial, and Post-Glacial Beds, with the position and probable relation of the hill-gravels throughout the south of England. The second part is devoted more especially to the consideration of the Post-Glacial Beds, particularly of those in the Thames and Hampshire Basins, and to the elaboration of his views respecting his Periods of Depression, Rise, and Glaciation. These papers, however, are not easy to summarize, but can be consulted with advantage.

The reader will also find in a paper by Mr. F. C. J. Spurrell,

* Quart. Journ. Geol. Soc. vol. xxiii. p. 394 (1867).

† *Ibid.* vol. xxiv. p. 283 (1868).

‡ *Ibid.* vol. xxiv. p. 464 (1868).

§ *Ibid.* vol. xxvii. p. 3 (1871).

‖ "On the Newer Pliocene Period in England, Part I.," Quart. Journ. Geol. Soc. vol. xxxvi. pp. 457–528 (1880); Part II., *ibid.* vol. xxxviii. pp. 667–745 1882).

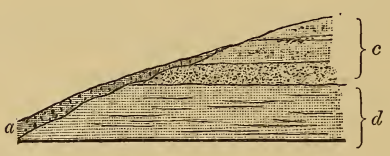
F.G.S. *, a notice of many of the hill-gravels of the London district, including the outliers on Shooter's Hill, Warley, Epping, Langdon Hill, and others, which he refers, with Mr. S. Wood, to the wreck of local Bagshot Beds.

The admirable "Drift Edition" maps of the Geological Survey, show the intricate ramifications of the Glacial and Post-Glacial Drifts in Suffolk, North Essex, and part of Herts (Maps 48, 47 †, and part of No. 7); but the Pebbly Gravel (Westleton) in Essex ‡, owing, I presume, to its being almost invariably hidden under Glacial beds, is not represented. Although, however, in that county the Westleton Beds are generally covered by Boulder-clay, the cuttings on the Great Eastern Railway which I had the opportunity of seeing showed that throughout that district they pass under the Glacial Series, and so help to connect the Hertfordshire, Buckinghamshire, and other outliers with the Westleton Shingle of Suffolk. These sections I will now proceed to describe.

2. *Range inland of the Westleton Beds.*

Suffolk.—In the westward range of the Westleton Beds, sands predominate in some places, shingle in others—often finely stratified and false-bedded. Besides their distinctive composition, they may generally be distinguished at sight by their pure white or ochreous colour, in contrast with the red of the Crag or the light drabs of the Glacial gravels. They pass, south of Westleton, from off the Chillesford Clay on to the unproductive sands of the Crag, as shown in the following section (fig. 1):—

Fig. 1.—*Pit on Rundell's Farm, Leiston Common* (1860).



a. Trail.
b. Boulder-clay not seen in pit, but showing a short distance higher up on the hill.
c. White sand, with seams of flint and white quartz-pebbles (Westleton).
d. Laminated ferruginous and yellow sands, ochreous and ferruginous sands.

Speaking of this district, Mr. Whitaker notices "a deposit of less certain classification which has been mapped only over the small tract north of the Minsmere Level. This is a gravel, with occasional sand, composed for the most part of pebbles (chiefly of flint, but some of quartz): and whilst it seems to underlie the lowest beds of the Glacial Drift, rests generally irregularly on the

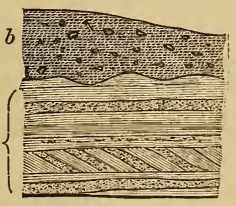
* 'A Sketch of the History of the Rivers and Denudation of West Kent,' 1886.
† Excepting the extreme N.W. corner and Hertford Heath.
‡ Geology of the N.W. part of Essex and the N.E. part of Herts, with parts of Cambridgeshire and Suffolk, 1878.

Crag sand" *. Two pits near East Bridge where it is to be seen are also noticed †. Mr. S. Wood, on the other hand, was of opinion that most of these gravels, as well as those of which we shall have to speak in East Essex, belong to his Middle Glacial.

Eastward of this place the shingly sands pass apparently over the Crag of Sizewell Gap; while to the westward they form part of the sandy commons and heaths of the Snape and Tunstall districts, but definite sections are wanting.

To the west of Wickham Market, a bed of white gravel and sand is worked in several small pits; and in one near Easton indistinct traces of shells are observable in some thin intercalated seams of ironstone. The furthest point inland here at which I have seen the Westleton Beds is under the Boulder-clay at Brandeston (fig. 2). There may, however, be a little doubt about this determination.

Fig. 2.—*Section at Brandeston Brick-pit* (1847 ‡).



b. Dark bluish-grey Boulder-clay.
c. Light-coloured coarse quartzose sand with seams of gravel consisting largely of flint-pebbles and some of white quartz, with a few fragments of shells.

At Ufford Bridge, between Wickham Market and Woodbridge, the Westleton Shingle rests on the Red Crag, with the Boulder-clay above it. At Kyson or Kingston, near Woodbridge, the railway-cutting exposed a fine section of the Red Crag and overlying sands, capped by a bed of Westleton Shingle. The following are the local particulars; a general section is given in Plate VII. fig. 8 §.

	feet.
1. White gravel of flint- and quartz-pebbles (Westleton)	2
2. White and light yellow sand	2
3. Bright yellow sand without fossils.....	28
4. Gritty sand, false-bedded and with local and irregular seams of shells, and an underlie of a few inches of gravel resting on	
5. A thick bed of Red Crag, abounding in shells at the west end of the cutting, but with very few at the east end	
6. A thin seam of Coprolites with flint- and a few other pebbles resting on a floor of London-Clay Septaria	
7. London Clay.	

* Mem. Geol. Survey, Quarter-Sheets 49 S. and 50 S.E. p. 27 (1886).
† See Quart. Journ. Geol. Soc. vol. xxxiii. pp. 101–111 (1877).
‡ I give dates, because in all probability many of the sections no longer exist.
§ See also Quart. Journ. Geol. Soc. vol. xxvii. p. 334.

The Shingle (No. 1) is approximately composed of:—

	per cent.
1. Flint-pebbles	30
2. White quartz-pebbles	30
3. Subangular flints	20
4. Subangular fragments of chert and ragstone	12
5. Pebbles of light-coloured quartzite, sandstone, greyish arkose, and dark metamorphosed slate	8
	100

Its thickness is uncertain, as the Boulder-clay does not show until the higher part of the hill is reached.

West of Woodbridge the Westleton Beds have undergone considerable denudation, and are generally removed and replaced by Glacial gravels and Boulder-clay. They, however, sweep round to the north of this area, and were to be seen in some small exposures in pits north-east of Ipswich.

At Finnford Bridge the section gave:—

		feet.
b.	Bluish Boulder-clay with chalk pebbles, &c.	6
	Seam of laminated brown clay	½
c.	White sands and gravel, the lower part false-bedded.	12

In the lane leading from Witnesham Street to Tuddenham I took the following section:—

		feet.
b.	Light brown Boulder-clay	5
c.	White sands and gravel (Westleton)	2 to 4
e.	Red Crag	8

In the fine section described by Mr. Whitaker * near Bramford, 3 miles north-west of Ipswich, he expresses an opinion that Bed No. 2 may be of Crag age. I would take it to represent the Westleton Beds. The following is Mr. Whitaker's description of this pit. Beds 3 to 6 are given only in abstract †.

	feet.
1. Glacial drift. Gravel and sand, resting irregularly on 2	up to 8
2. Fine light-coloured sand with thin clayey layers; at the bottom a thin layer of gravel with phosphatic nodules (may belong to the Crag)	up to 15
3 & 4. London Clay with a Pebble-bed at base	10
5. Reading Beds with a few flints and pebbles	18 or more
6. Thanet Sands	5
7. Chalk.	

Three miles south-west from the last pit is the village of Burstall, and on the slope of the hill on the banks of the small stream I found (1856) the following section:—

		feet.
b.	Boulder-clay, chalky	3 to 10
c.	White gravel or shingle (Westleton)	8 to 10
	White sands	2

* Mem. Geol. Survey, 'Geology of Ipswich,' &c., 1885, p. 14.

† This pit had not been opened out to its full extent when I last visited it several years ago.

Lower down the hill the yellow sands of the Crag crop out.

The gravel has the well-marked characters of the Westleton Shingle, its approximate composition being as under :—

	per cent.
1. Small flint-pebbles	30
2. White quartz-pebbles	25
3. Subangular flints	23
4. Subangulaar fragments of chert and ragstone	12
5. Pebbles of light-coloured sandstone and quartzite, and Lydian stone	10
	100

Mr. F. J. Bennett has noticed a very similar section at Elmsett, 3 miles to the north-west of Burstall, where the Boulder-clay overlies a "rather coarse sandy gravel, with pebbles of quartz and of quartzite, about 2 to 10 feet," overlying a "fine buff rather clayey sand" *.

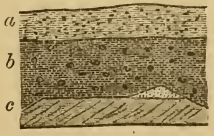
The railway-sections in this intermediate district afforded little information respecting the Westleton Beds. The Norwich line, between Ipswich and the valley of the Ottley stream, passes almost exclusively through thick Boulder-gravels and clay very much disturbed and deeply eroding the underlying beds; whilst the Yarmouth line, between the Orwell and the Deben, passes through Glacial loams, with but little gravel or Boulder-clay, overlying the Red Crag and unfossiliferous sands.

My notes, I regret to say, are not sufficiently detailed to give a definite account of the deep cutting on the northern side of the tunnel at Ipswich on the London line. This section, unlike that on the southern side of the tunnel, which was through a mass of Post-Glacial Drift, exposed :—

	feet.
Light-coloured sands with seams of gravel in horizontal layers	40
Red Crag with much false-bedding †	20
Dark brown London Clay.	

But though I failed to note the exact composition of the gravel, my belief is that this bed belongs to the Glacial Series. The next cutting (fig. 3), where the line passes under the London Road, shows how extensive the denudation accompanying the advance of the Boulder-clay has been.

Fig. 3.—*Section on the Railway near Ipswich.*



a. Ochreous gravel. *b*. Boulder-clay. *b'*. Light-coloured gravel. *c*. Red Crag.

* 'Geology of Ipswich,' &c., p. 77.

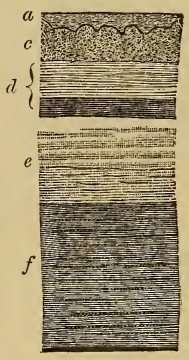
† Here, as at the Kyson Cutting, a layer of Septaria divides the Red Crag from the London Clay.

Essex.—On the south of the Crag area, the well-known cliffs at Walton-on-the-Naze exhibit a small patch of the Westleton Beds, composed of:—

	per cent.
1. Flint-pebbles	36
2. White quartz-pebbles	20
3. Subangular flints	20
4. Subangular chert	14
5. Quartzites, Lydian stone, &c.	10
	100

This gravel caps the cliffs near their western extremity, overlying a bed seemingly of the Chillesford Clay *. At the eastern end of the cliff, the unproductive sands are replaced by very fossiliferous beds of the Red Crag.

Fig. 4.—*Section of Cliff east of Walton-on-the-Naze.*



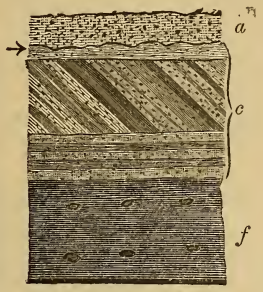
		feet.
a.	Surface-soil and gravel	1 to 2
c.	Westleton Shingle	5
d.	Light-coloured laminated sands and clays	4
	Dark carbonaceous clay with much wood and lignite	2
e.	White and yellow sands. These are replaced at the other end (east) of the cliff by fossiliferous Red Crag	10
f.	London Clay.	

From Walton to Clacton the low cliffs consist of London Clay capped by gravel. There are no Crag Beds. This gravel forms apparently one thick bed (12 to 20 ft.), but in reality it consists of two parts. The upper bed is much disturbed and not stratified, and is derived in considerable part from the *débris* of the lower bed; whereas the lower one is regularly stratified, and often shows well-marked false-bedding. It may be a question whether, although both the Red Crag and the Boulder-clay are absent in these cliffs, the lower gravel should not be referred to the Westleton Shingle. That there is a material difference of age between the two beds of gravel

* Mr. Clement Reid considers it to be something newer.

is evident from the circumstance that at the Clacton end of the cliffs these gravels * divide and admit between them the Post-Glacial mammaliferous deposit described by the late Mr. J. Brown and by the Rev. O. Fisher †.

Fig. 5.—*Section of the Cliff one mile south-east of Clacton.*



	feet.
a. Coarse ochreous Gravel	4 to 6
?*c*. Alternating beds of fine and worn gravel, finely bedded or with oblique lamination. Colours ochreous, white, and dark ferruginous	8 to 12

f. London Clay.

At Clacton the two gravels are divided at → by the Post-Glacial clays mentioned above.

The Lower Gravel, which is imbedded in a matrix of loamy brown quartzose sand, quartz-grit, with innumerable fine fragments of flint, is composed as under :—

	per cent.
1. Flint-pebbles	24
2. White quartz-pebbles	16
3. Subangular fragments of flint, mostly white, but a few stained brown	32 ?
4. Subangular fragments of white and yellow cherty ragstone	10
Subangular fragments of brown and red chert	8
5. Pebbles of light-coloured (?) quartzite, dark sandstone, and Lydian stone	10 ?
	100

I have, however, some doubts about this correlation. The bed may be of Post-Glacial age.

It is also a question whether some of the thick gravels of Central east-Essex may not be of Westleton age ‡. Some well-sections seem to indicate that such is the case in respect to the base of the great spread of gravel west of Colchester. This bank is from 30 to 50 feet thick, and the upper part consists of gravel of Glacial age. It may be seen from the railway-sections how closely associated

* The surface of the lower gravel should be examined for palæolithic flints.

† Mag. Nat. Hist. ser. 2, vol. iv. p. 197 (1840); Geol. Mag. vol. v. p. 214 (1868). See also the Survey Memoir by Mr. W. H. Dalton.

‡ The Rev. O. Fisher informs me that the pebble-gravel is well developed at Elmstead, near Colchester, and at Alresford, near St. Osyth.

the Glacial and Westleton Series are in some parts of Essex, and how difficult, without the intervention of the Boulder-clay, it sometimes is to distinguish between them.

There is no group of sections in Essex more interesting than those adjacent to Sudbury. The Chalk, the Lower Tertiary Beds, together with Pre-Glacial, Glacial, and Post-Glacial Drifts, are there exhibited in the same or in neighbouring pits. Since I visited them they have been fully described by Mr. Whitaker, to whose sections I would refer the reader *. The Pre-Glacial beds are exposed at some of the pits on Balingdon Hill, where the Boulder-clay reposes upon so irregular a surface that in some places it rests on Pre-Glacial Sands, in others on some of the Tertiary strata, and in others on the Chalk.

On my first visit to these pits in 1845, I was inclined to believe that the thick bed of sand and gravel under the Boulder-clay belonged to the Crag; but later, I was led to conclude, on the score of position and composition, that it should be grouped with the Westleton Beds. I found no fossils; but Mr. Whitaker has since then found traces of shells (broken) with unbroken specimens of *Purpura lapillus* (var. *crispata*); and in another pit he discovered a bed of sandy ironstone, with casts of shells, of which 11 species (*op. cit.* p. 31) were determined, though with doubt, by Mr. Etheridge. With them were a few coprolites. On these grounds Mr. Whitaker classes this bed with the Red Crag, with a query.

The Red Crag has not, however, been met with within a considerable distance, and the fossils found are of a negative character. The *Purpura lapillus* occurs in the Westleton Beds of Norfolk and Suffolk—as also species of *Natica*, *Cardium*, *Mytilus*. Or the fossils and the coprolites may have been derived from the Red Crag; for the beds under the Westleton shingle are, as will be shown further on, often greatly eroded. Or we may have here a remnant of Red Crag at the base of sands and gravel belonging to the Westleton Series.

I express this opinion, however, with all reserve, though I think it is confirmed, not only by the section at Burstall, but also by one nine miles to the west of Sudbury, at a place called Burnt House, near Stoke (fig. 6). In the pit there a very similar, but much thicker bed of gravelly sands is seen resting on the Chalk, while the Boulder-clay is worked in another pit just above.

I found no fossils at this place; but they have been since recorded by the officers of the Survey, who give the following description of the pit †:—

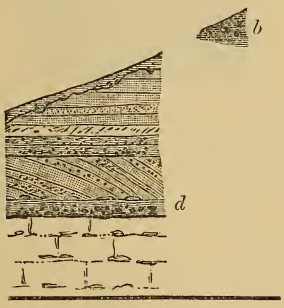
	feet.
"Glacial Drift. White, grey, and yellow false-bedded sand, partly coarse, partly fine, irregularly bedded. A mass of shells (*Purpura lapillus*) said to have been found at the bottom at one spot (? Crag)	30
? Drift or Red Crag. Bed of flints &c. (a piece of phosphatized bone)	1 to 2
Chalk, bedded, with flints	30"

* Mem. Geol. Survey. Geology of the N.W. part of Essex &c. pp. 14, 16, 31, 57 (1878); and *op. cit.* p. 132 (1885).

† Mem. Geol. Survey. Geology of the N.W. part of Essex &c. p. 49 (1878).

I omitted to notice whether chert and ragstone were present, nevertheless the composition and character of the sands and shingle are, I think, of the Westleton type. Both flint- and quartz-pebbles occur, it is true, in the Red Crag *, but never in such numbers, or proportion, as to form a compact bed of shingle like that of Westleton.

Fig. 6.—*Section at Burnt House, near Stoke* (1848).



feet.

b. Bluish Boulder-clay exposed in another pit a short distance higher on the hill.

c. Bright yellow and white micaceous sands, fine at top, coarse below, succeeded by fine gravel or shingle. The sands show oblique lamination, and contain concretions or balls of soft limonite, some 1 foot in diameter 25

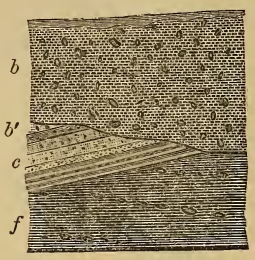
d. Layer of large flints, angular and rounded.

The railway between Sudbury and Mark's Tey exposed some interesting sections. The first deep cutting, 2 miles south of Sudbury, showed 5 or 6 feet of ochreous flint-gravel and sand, overlying from 5 to 10 feet of greyish-blue clay (Glacial), of which the lower part was finely laminated. Beneath this were 4 or 5 feet (base not reached) of white and yellow sands with seams of small shingle (Westleton?). The Lamarsh and other smaller cuttings were through Post-Glacial brick-earth and gravel. Between Bures and Chapple, the cutting passed through 12 feet of a blue Boulder-clay, separated from 10 feet of a brown Boulder-clay by 2 feet of ochreous gravel. Below the Boulder-clay was a bed, 4 feet thick, of ochreous gravel, under which were 7 or 8 feet of white sand and gravel (Westleton).

But the most important cutting was that between Chapple and Mark's Tey. It extends for nearly a mile, and reaches a depth of from 20 to 25 feet. At the two ends, the section exposed from 8 to 10 feet of Boulder-clay overlying Westleton Shingle, but in the centre resting on London Clay. The whole section is given at length in Pl. VII. fig. 7. A small enlarged portion is given below (fig. 7).

* Reference will be made to these in the third part of this paper.

Fig. 7.—*North end of the Railway Section between Chapple and Mark's Tey* (1849).



	feet
b. Bluish-grey Boulder-clay	12
b'. Coarse ferruginous gravel	2
c. Stratified sands and shingle, yellow and bright ferruginous ochreous (Westleton)	6
f. London Clay.	

No fossils were found in any of the sections, except in some Post-Glacial Beds at Sudbury and Lamarsh.

Similar sands and shingle have apparently a considerable development in North Essex; but they are generally hidden by Boulder-clay, or masked by Glacial gravel, which, when fine and stratified, they resemble in general appearance, and sometimes assimilate to it in composition, owing to an admixture of the two beds. On a hill $1\frac{1}{2}$ mile north of Coggleshall there was a section showing 4 feet of Glacial gravel overlying 6 feet of bright yellow and ochreous sand with flint- and white quartz-pebbles (Westleton).

The Witham and Braintree branch line likewise exhibited some very illustrative sections of the Glacial and Westleton Beds (figs. 8, 9).

Fig. 8.—*Section on the Railway, one mile north of Witham.*

a. Brick-earth. } Post-Glacial.
a'. Flint-gravel. }
b. Chalky Boulder-clay.
c. White sand with shingle at base (Westleton).
f. London Clay.

The shingle consisted of—

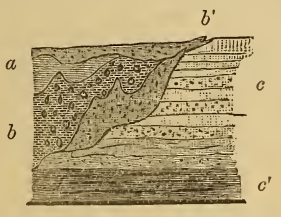
	per cent.
1. Flint-pebbles	32
2. White quartz-pebbles	24
3. Subangular fragments of flint	35
4. Subangular fragments of chert and ragstone	9
	100

Similar beds were passed through at various cuttings between this point and Bulford; but it was between Black Notley and Braintree that the section of greatest interest was exposed. The cutting, which is 25 feet deep, showed the Chalky Boulder-clay resting upon a deeply indented surface of coarse Glacial gravel, much contorted. This latter had likewise ploughed heavily into the underlying light-coloured Westleton sands and shingle, which were regularly stratified in horizontal layers, and intersected by a number of small faults of $\frac{1}{4}$ to 3 feet throw, which did not pass upwards into the Glacial Beds (Pl. VII. fig. 6).

The shingle consisted mainly of small flint- and white quartz-pebbles with a few subangular flints. No fossils were found. The overlying Glacial gravel consisted of large worn flints and some Chalk-*débris*, with pebbles of sandstone, of red quartzite (N.R.S.), and some small pebbles of flint and white quartz, the latter probably derived from the underlying beds. (See explanation of Pl. VII. p. 152).

The Westleton Beds were again exposed at the ballast-pit near Braintree Station. They are there much more ferruginous than usual, and are deeply indented by the overlying Glacial clay and gravel. In one part of the pit the section was as under (fig. 9):—

Fig. 9.—*Railway ballast-pit, Braintree* (*south end*) (1848).



		feet.
	a. Brown clay with subangular flints... } Very variable and local.	
	b. Very chalky Boulder-clay ..... }	
	b'. Ochreous Gravel (Glacial) ..... }	
Westleton Beds.	*c*. Finely stratified white sands and gravel, yellow in the lower part	13
	c'. Coarse dark ochreous gravel, with ferruginous concretions	4

The shingle consisted of the following materials, placed in the order of their relative abundance:—

1. Flint-pebbles.
2. Pebbles of white quartz.
3. Subangular flint-fragments.
4. Subangular fragments of chert and ragstone.
5. Large flattish light-coloured quartzite-pebbles.
6. Subangular pieces of Tertiary sandstone and puddingstone.
7. Small Lydian stones and pieces of white quartz.

Beneath *c'*, a hole sunk at the bottom of the pit showed 8 feet of interstratified white and yellow sands, with a shingle composed

largely of white quartz-pebbles. This gives a thickness at this spot of 25 feet of Westleton Beds; but these sands and gravels extend nearly to the top of the hill on which Braintree stands, and as the well at the waterworks lower down shows that the base of the sands is there 140 feet above O.D., while the summit of the hill is above 234 feet, the Westleton Beds, round which the Glacial Beds wrap, would seem to be here not less than from 70 to 80 feet thick (see Pl. VII. fig. 1).

It would appear from this and other instances to be named that these Westleton Beds had a large development in Central and Northern Essex, but that that they have been extensively denuded by the overlying Glacial drifts. The independence of the Westleton Beds in respect to those of the Glacial Series here also becomes more apparent, owing to the rise of the land and its waste before the deposition of the Glacial Beds, in consequence of which the latter, in the districts further to the west, where the rise was greatest, gradually come to occupy a lower level than the former. The separation of these two Drift-series, first clearly apparent in this part of Essex, becomes more pronounced as we proceed westward in the London Basin. The presence of Chalk and Jurassic *débris*, with Quartzite pebbles derived from the New Red Sandstone, readily serves to distinguish the Glacial from the Pre-Glacial drifts.

The Westleton Beds extend to the north-west, though but rarely exposed, by Wethersfield to Dunmow and Thaxted. In a pit just south of the latter place is a section of some interest (fig. 10), as the pebbly sands, which I take to be of Westleton age, and the overlying Boulder-clay are both faulted. This, however, is from recollection. I omitted at the time to note the constituent parts of the gravel. The Survey officers consider it to belong to the Crag.

Fig. 10.—*Section near Thaxted* (1850).

a. Pebbly soil.
b. Whitish Boulder-clay.
c. Coarse white sands with a few patches of gravel.
c'. Ferruginous sand.

The Westleton Beds again showed in a pit at Braxted, 2 miles S.W. of Thaxted, the section of which was as under:—

1. Gravelly sand and clay.
2. White chalky Boulder-clay.
3. Ochreous gravel, consisting essentially of flint- and quartz-pebbles, with very few subangular flints.
4. Ochreous sand.

To return to the main line of railway. The sections from Witham to Manningtree are all through Glacial or Post-Glacial Beds, and are not of importance; while on the branch line to Maldon they are chiefly through London Clay and Post-Glacial gravels.

Maldon stands on a hill about 120 feet high, capped by gravel probably of Westleton age. My notes refer to it as a flint-shingle with quartz-pebbles and fragments of chert.

Danbury Hill, 6 miles S.S.W. of Witham, and 317 feet high, is capped by gravel of an anomalous character. It consists chiefly of subangular flints with a large proportion of flint-pebbles, and a few pebbles of quartzite, quartz, chert, and some old rock having more the character of a Glacial Drift. It may have been a Bagshot outlier invaded by the Glacial gravel. Lower down (about 150 feet) on the southern slope of the hill is another gravel in which chert- and quartz-pebbles are more prominent.

At the cutting on the main line which begins one mile west of Witham, and which reaches in places a depth of 25 feet, a very white chalky Boulder-clay passing down into bluish grey, overlies 5 feet of white sand with a seam of flint- and quartz-pebbles (Westleton) at base. At the western end of the cutting the same gravel, but with ochreous and white seams alternating, lies in hummocks beneath the Boulder-clay. The Hatfield cutting is through 20 feet of gravel at the eastern end, and through chalky Boulder-clay capped by 8 feet of brick-earth at the west end.

The long cutting from Springfield to Chelmsford (30 feet deep in the centre) is of interest from its showing the great erosion of the London Clay and the very irregular distribution of the gravel and Boulder-clay; but my notes relating to the gravel which underlies the Boulder-clay are insufficient for me to say whether it is of Glacial or of Westleton age.

A range of hills, capped by pebble-beds, commences a short distance westward of Chelmsford. But these, though really older than the Westleton Beds, I have relegated to Part III. of this paper. They include Writtlepark, Brentwood, Rayleigh, and other hills.

The Westleton Beds, which thus far have not reached a level of above 160 to 200 feet, now rise more rapidly as they trend westward, capping the hill-tops, and leaving the Boulder-clay and the Glacial gravels at lower levels in the intermediate lower ground. There is thus a considerable break before the next outliers are reached, though there are, I think, traces of the Westleton Beds to be met with near Ongar.

The next well-defined outliers are therefore on the western side of the valley of the Roding, on the range of the Epping hills, which at Highbeech and Jack's Hill attain a height of from 340 to 370 feet. On the top is a well-marked bed of the Westleton Shingle. The following is its approximate composition in a pit near the "Wake Arms," Jack's Hill:—

	per cent.
1. Flint-pebbles	50
2. White quartz-pebbles	15
3. Subangular fragments of flint	20
4. Subangular fragments of chert and ragstone	10
5. Pebbles of Lydian stone &c.	5
	100

A bed of white and yellow sand (Bagshot) underlies the gravel.

At Coopersale Common (or Gaynes Park), two miles N.E. of Epping, is another range of hills, from 340 to 360 feet high, on which there is also a capping of Westleton Shingle composed of

	per cent.
1. Flint-pebbles	56
2. White quartz-pebbles	20
3. Subangular fragments of flint	9
4. Subangular fragments of white Ragstone	12
5. Pebbles of Lydian stone &c.	3
	100

imbedded in a matrix of light yellow, loamy, quartzose sand.

To the south of these, and extending from Buckhurst Hill to Woodford Hill, is a considerable spread of pebbly gravel, 10 feet thick in places, of a character intermediate between the Brentwood and the Westleton Beds, but more analogous to the former. It consists almost entirely of flint-pebbles (Bagshot), with a very few white quartz- and other rock-pebbles imbedded in a variable matrix of sand and clay. The lower part is roughly stratified—the upper passes into an unstratified mass of brown and ferruginous clay with few flint-pebbles.

Middlesex.—The Drift Beds of the eastern and lower part of the county consist chiefly of Glacial and Post-Glacial gravels; while the higher hills on the north are capped by the Westleton Shingle. Thus the ridges from Barnet and Barnet Gate (410–460 feet), and from Totteridge to Highwood (400–410 feet), and again at Mill Hill, are capped by a poor gravel of this age, from 2 to 5 feet thick, and composed of

	per cent.
1. Flint-pebbles	50
2. White quartz-pebbles	15
3. Subangular flints, stained white and brown	20
4. Subangular ragstone and chert	12
5. Lydian stone &c.	3
	100

in a matrix of quartzose sand and greenish clay.

The Boulder-clay, at a level of about 100 feet lower, extends from Whetstone to Finchley and Muswell Hill. The gravel which underlies it in a pit near Finchley Church is of Glacial origin, and is full of northern *débris*. That at the old section opposite to the "Bald-faced Stag" has been referred to the Pebbly Gravels;

I should have placed it also with the same Glacial Beds; but my notes are insufficient.

The Westleton Beds are difficult to follow in this direction. They do not seem to rise so high as further north. Some beds at Hendon (280 feet) may possibly be referred to them, as also a small outlier which caps the hill (278 feet) at Horsington, two miles south of Harrow. This isolated patch, which is a mere remnant scattered on the surface, consists of

	per cent.
1. Flint-pebbles	42
2. White quartz-pebbles	10
3. Subangular flints stained brown	30
4. Subangular chert and ragstone	18
	100

With respect to Highgate and Hampstead Hills, which rise to the height 412 feet, I hesitate how to class them. I have found some fragments of worn cherty ragstone and a few rare quartz-pebbles on Hampstead Hill, with abundant flint-pebbles of local (Bagshot) origin; but the characters are not sufficiently marked to satisfy me. They may be Westleton or they may be outliers of the Southern Drift.

In the north of the county, a well-marked Westleton outlier may be seen in the wood (400 ft.?) $1\frac{1}{2}$ mile north of South Mimms, consisting of:—

	per cent.
1. Flint-pebbles	38
2. White quartz-pebbles	28
3. Subangular flints, not stained	24
4. Subangular chert &c.	6
5. Pebbles of white quartzite, Lydian stone, &c.	4
	100

The adjacent ridge, extending from Potter's Bar to Bell Bar (380 to 400 ft.), is also capped by a thin bed of Westleton Shingle, but there were no sections open at the time of my visits.

The Pebble-Beds of Stanmore, Elstree, and some adjacent hills belong to the Brentwood group.

Hertfordshire.—The London-Clay hills of the north of Middlesex, capped by Westleton Shingle, are continued into Hertfordshire, where they form, between Hatfield and Hertford Heath, a conspicuous range from 320 to 380 ft. high, and overlooking, at a level of from 180 to 240 ft. lower, the broad valley of the Lea and Mimram, over which are spread Glacial gravels and sands, covered in places by the Boulder-clay. The material difference of level and the marked character of the beds here bring out very clearly the discordant relation of these Glacial and Pre-Glacial Beds, as shown in the following section (fig. 11):—

Fig. 11.—*Section from Hatfield Brick-pit to the G. N. Railway near Digswell Junction.*

a. Post-Glacial beds.
b. Boulder-clay.
b'. Light-coloured sands and ochreous gravel.
c. Westleton Shingle.
T. Lower Tertiary strata.
C. Chalk.

Speaking of the characters of these gravels, Prof. T. M^{c}K. Hughes * says: "The gravel of the Upper Plain consists chiefly of pebbles; of these, about fifty per cent. are of quartz, about ten per cent. of quartzite, about five per cent. various (such as jasper and a conglomerate of quartz pebbles in quartzite), and the rest flint." These gravels have also been noticed by Mr. Whitaker and Mr. S. V. Wood in the papers before referred to.

This Hertfordshire shingle is remarkable for the large proportion of pebbles of white quartz and of Lower-Greensand débris †. A specimen from Brickenden Hill yielded broadly:—

	per cent.
1. Flint-pebbles	34
2. White quartz-pebbles	28
3. Subangular flints—2 stained brown, and 3 not stained	17
4. Subangular fragments of red and brown chert and of white ragstone	18
5. Pebbles of Lydian stone &c.	3
	100

Further to the south-west similar beds are met with at Shenley Hill and again a little northward at Bernard's Heath near St. Albans, where they form a bed from 8 to 10 ft. thick, capping Lower Tertiary Sands and Clays, at an altitude of 406 feet. They there consist of:—1. Flint-pebbles; 2. White quartz-pebbles; 3. Subangular flints, not stained; 4. Subangular cherty ragstone; 5. Pebbles of Lydian stone, yellow quartzite, &c.; imbedded in a loamy red and yellow mottled sandy clay, disturbed at top.

Notwithstanding the extreme denudation which the high Chalk-plain, extending from Hertfordshire into Bedfordshire, Buckinghamshire, and Oxfordshire, has undergone, a few small outliers of Lower Tertiary strata still remain, rising above the general level of the Chalk-plateau with its scanty Glacial Drifts and its "Red Clay with flints"

These little isolated hills are frequently capped by a gravel- or shingle-bed, which I believe to be of Westleton age. They are

* *Op. cit.* p. 285.

† The chert and ragstone débris does not seem to have been hitherto recognized, or is mentioned under some other name.

very few in number, and gradually become rarer as we proceed northwards, although in a few instances they extend to the edge of the Chalk Downs.

At Collier's End (348 feet) and Sacombe Green (362 feet), five miles north of Ware, are two small Lower Tertiary outliers with a thin capping of quartzose shingle (Westleton). Others lie on some of those near Welwyn,—on Ayot (406 feet) and Burnham Green (407 feet) hills.

North of St. Albans, and between the valleys of the Lea and the Gade, traces of Lower Tertiary strata may be found as far north as Berkhampstead Common, but they are rarely in sufficient force to be worked, or high enough to bring in the Westleton Beds. At Bennett's End, near Hemel Hempstead, the Tertiary strata are capped at a height of 456 feet by a bed of sandy clay with a thin uneven patch of Westleton gravel, consisting in large proportion of flint- and quartz-pebbles with a few subangular flints (not stained), fragments of Lydian stone, and a few flat ovate light-coloured quartzite-pebbles. The bed varies from 1 to 6 feet in thickness, and rests on from 30 to 40 feet of London Clay and Lower Tertiary strata.

There is another Tertiary outlier at Little Heath and Potten, extending to Berkhampstead Common, or rather it is a mass of Tertiary strata preserved in a depression in the Chalk, of great extent. There is some appearance of Westleton Shingle, but too indistinct for description.

The hills to the west of the Gade present similar features. The Tertiary Beds are, however, so mixed up with Glacial débris that they are to be recognized only in a few instances. At Langley Common (440 feet) there are traces of Westleton Shingle, and closely adjacent to the borders of Hertfordshire is the more conspicuous outlier of Tiler's Hill.

South Buckinghamshire.—In this county, as in Hertfordshire, the picturesque high ground of the Chilterns is covered by a sprinkling of Glacial Drifts (but no Boulder-clay), and "Red Clay with Flints," with occasional Tertiary remnants.

Tiler's hill*, 2 miles east of Chesham, rises to a comparatively considerable height above the surrounding Chalk-plateau, and consists of Lower Tertiary strata with an outlier of London Clay†. On the summit, about 600 feet above the sea-level, is a small capping of gravel, composed of:—

	per cent.
1. Tertiary flint-pebbles, small and large, many of them weathered white	55
2. White quartz-pebbles	23
3. Very subangular fragments of flint, stained yellow; others are large, white and little worn	12
4. Chert &c.	5
5. Flat ovate pebbles of light-coloured quartzite and veinstone, with subangular fragments of Tertiary sandstone and puddingstone	5
	100

* On the new one-inch map this name is altered to Crowcroft.

† Described by the author in Quart. Journ. Geol. Soc. vol x. p. 90 (1854).

The gravel rests on an uneven bed of London Clay. Lower Greensand débris is comparatively scarce, and the débris of Tertiary rock more abundant, while pebbles of the older rocks are rare.

There are several Tertiary outliers on the high Chalk-plateau between the Misbourne and the Wye. One of these, to the west of the village of Penn, near Beaconsfield, rises to the height of about 600 feet, and is capped by a well-marked bed of Westleton gravel like that on Tiler's Hill, while another gravel (Glacial?), derived in part from the Westleton Shingle, lies on the Chalk-plain at Penn (547 feet) and Penn Common. At Lane End (600 feet), four miles west of High Wycombe, there is also an outlier of Lower Tertiary sands and clays, capped by a similar gravel of flint- and white quartz-pebbles, subangular flints weathered white, with a few old-rock-pebbles (see Pl. VII. fig. 1).

South Oxfordshire.—From the borders of Buckinghamshire to the Thames between Pangbourne and Wallingford there are but few Tertiary outliers. The most conspicuous of these is that at Nettlebed hill *. The Westleton Shingle (?) there attains its highest level of about 650 feet. It is but a small patch, and presents a less definite composition than the others, as might be expected from its distance from the main body.

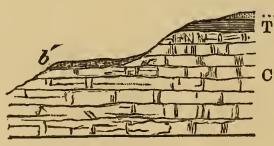
The shingle, which reposes upon a very uneven surface of the Lower Tertiaries, consists approximately of :—

	per cent.
1. Tertiary flint-pebbles	54
2. Small pebbles of white quartz	14
3. Subangular flints, not stained	20
4. Chert &c?	4
5. Pebbles of hornstone (?), veinstone, and Sarsen stone	8
	100

imbedded in a matrix of light quartzose sand.

Five miles S.W. of Nettlebed, and close to the edge of the Chalk escarpment overlooking the plains of Oxfordshire, a thin outlier of Lower Tertiaries (the mottled clays of the Reading Beds) overlies the Chalk at Greenmoor hill (560 to 600 feet) and Woodcote Common, about 3 miles east of Goring. It is capped by a well-

Fig. 12.—*Section on the hill above the Thames, near Goring.*



c. Westleton Shingle. | T. Lower Tertiaries.
b'. Glacial Gravel. | C. Chalk.

defined bed of Westleton Shingle, which is in marked contrast with the Glacial gravel, with its New-Red-Sandstone quartzites, which sets

* Described in Quart. Journ. Geol. Soc. vol. x. p. 89 (1854).

in near Coomb End at a short distance from it westward, and at a level of about 100 feet lower (fig. 12). This is the most distant outlier in this direction, and from its position on the edge of the Chalk Downs overlooking the Great Oolitic plains, possesses more than usual interest (see Pl. VII. fig. 1).

The shingle forms an ochreous sandy gravel, consisting largely of subangular flints much worn, flint-pebbles, and with none of the New-Red-Sandstone quartzites so common in *b'*. I noted at the time that it is much like the gravel on Bowsey hill (*infrà*). Approximately it was composed of:—

	per cent.
1. Tertiary flint-pebbles, of which some were broken	44
2. White quartz-pebbles	10
3. Subangular and angular pieces of flint	30
4. Subangular pieces of Sarsen stone, of a hard dark sandstone, and of ironstone (Tertiary)	9
5. Flat ovate pebbles of light-coloured quartzite, with small pebbles of Lydian stone (?), and of a quartz-grit	7
	100

I failed to note either Chert or Ragstone.

A few miles to the south another Tertiary outlier extending from Chazey Heath to Rose Hill (300 to 350 feet) is capped, but not very distinctly, by a light-coloured gravel very similar to the above, while the intermediate and lower areas are overspread by the Glacial gravel, but Boulder-clay is absent.

Further to the south, as we approach the Thames, the valley-gravels set in and continue to the Berkshire side.

Berkshire and Wiltshire.—Between Reading and Maidenhead * the broad valley of the Thames, with its Post-Glacial gravels, becomes greatly contracted between Henley and Marlow by the high ground of Cookham Dean (350? feet) and Bowsey Hill, which is 467 feet high, or 350 feet above the Thames at Henley. The former of these hills is bare to the summit, whereas the latter is capped by a light ochreous sandy and pebbly gravel, from 5 to 8 feet thick, of a characteristic Westleton type. The following are its component parts, but I failed to note their relative proportion:—

1. Tertiary flint-pebbles, some of them entirely decomposed.
2. Numerous small white quartz-pebbles.
3. Subangular fragments of flint, weathered white.
4. Very few subangular fragments of white ragstone and one of fossiliferous chert.
5. Pebbles of light-coloured quartzite, yellow sandstone, and rose-coloured quartz-grit, with some small pebbles of veinstone, Lydian or hornstone, greenstone?, and red and grey quartz.

The quartzites are not the red and grey quartzites of the northern Drift.

* It would seem probable that the Thames at an early stage may have flowed in a direct line from Twyford to Maidenhead, by way of the valley of White Waltham, which offers a low and straight course, instead of the circuitous course it took in Post-Glacial times through the Henley and Cookham Hills.

The Berkshire Downs, which form the prolongation of the Chiltern Hills of Buckinghamshire and Oxfordshire, rise above Streatly and Goring to the height of from 400 to 600 feet. In the line of the Thames Valley there is a broad high terrace of Glacial Drift, whilst at a little distance further from the river the Westleton Shingle appears on a relatively higher level. The Glacial gravel forms a terrace at Southridge, and between Basildon and Ashampstead, at a level of about 400 to 420 feet, whilst the Tertiary outlier at Upper Basildon is capped by Westleton Shingle. The Tertiary outlier (350 to 380 feet) north of Bradfield is also capped by a gravel which may be of the same age.

The Chalk Downs of Berkshire are much barer than those of Oxfordshire and Buckinghamshire both of Tertiary outliers and of Drift. The former are extremely scarce until we approach the borders of the Tertiary basin near Newbury. Nevertheless it is probable that the Westleton Shingle extended over this area, for I found on the bare Chalk-hills above East Compton a pocket of Tertiary Sands and Drift, with flint- and quartz-pebbles, &c.,—a remnant probably preserved, like the Crag at Lenham, by the chance circumstance of its being in a pipe or hollow in the Chalk.

To the north and north-west of Newbury there are several gravel-capped hills, possibly of this date, such as Donnington Common and the hill east of Basford. One of the most prominent is that at the end of the spur of Tertiaries which extends north-westward from Newbury to Wickham. This hill, which is 560 feet high and rises 100 feet above the surrounding Chalk-plain, consists of Lower Tertiary strata (including the base of the London Clay)*, and is capped by a bed of gravel, from 3 to 5 feet thick, composed of flint-pebbles, with subangular flints imbedded in a quartzose sand and grit very much worn. From its position and general character I think it may be of Westleton age, but I have no note of its exact composition.

The bare Chalk-plains of East Berkshire and Wiltshire offer scant opportunities for determining the presence of the Westleton Shingle. Except in a few rare instances denudation has swept these plains clean of all but the superficial soil and trail. The higher Chalk-hills near Baydon, 8 miles E.S.E. of Swindon, are, however, capped by a gravel consisting of subangular flints and Tertiary flint-pebbles, with some quartz-pebbles; and a similar ridge to the east of Ogburn St. George, on the north-east of Marlborough, is also capped by a little flint-gravel with quartz-pebbles.

Quartz-pebbles also occur in places in flint-drift on the hills about 2½ miles south of Marlborough†. Patches of a pebbly drift again occur on the higher points of the Chalk Downs at Bishopstone near Shrivenham and at Liddington and Basdrop to the south of Swindon, but they are very indistinct.

* Described in Quart. Journ. Geol. Soc. vol. x. p. 86 (1854).

† The Drift-beds of this district have been described by Mr. T. Codrington, in the Magazine of the Wiltshire Archæological and Natural History Society, 1865.

The last trace of such drift I have met with on these Chalk Downs was on Monument Hill above Calne, where there are a few scattered pebbles of white quartz, quartzite, chert, and ironstone, with subangular flints and flint-pebbles, but its exact relation is uncertain.

3. *Westleton Beds on the South of the Thames.*

The Boulder-clay, it is well known, has not been found south of the Thames, though some Pre-Glacial beds have a considerable extension in that direction, and evidence of glacial action is not wanting. Owing, however, to their isolation and want of continuity the classification of these beds is attended with more uncertainty.

Kent.—In the north-eastern corner of Sheppey the cliffs at Draper's Point, there about 170 feet high, are capped by a Drift distinct from that which is spread over a great part of the higher ground of that island. It consists of from 15 to 20 feet of yellow sands with seams of clay and patches of gravel, the bottom bed of gravel being from 1 to 2 feet thick, and composed essentially of flint-pebbles of various sizes, of large subangular flints much worn and stained brown, numerous small flint-fragments, and some very small pebbles of quartz, and at one spot I found a much worn fragment of brown chert. It is not improbable that these beds are of Westleton age. They are overlain by a flint-gravel in small pockets.

I know of no other bed of this character in Kent, except one between Shottenden Hill and Sellings (400 feet), where there is a sprinkling of Drift consisting of Tertiary pebbles and pebbles of quartz. But both these cases are obscure.

I do not refer the shingle on the top of Shooter's Hill or the gravel on Swanscombe Hill to this horizon.

Surrey and Hants.—Further westward traces of the Westleton Beds become very indistinct. There are remnants of a quartz-drift at Englefield Green (264 feet) and on some adjacent hills; but it is another Pre-Glacial high-level gravel-drift (see Part III.) that prevails almost exclusively in this district.

4. *Possible Extension of the Westleton Shingle beyond the Thames Basin into Somerset.*

Passing from the Chalk Downs to the Oolitic Hills further westward, there is at one spot, Kingsdown near Bathford, about 550 feet high and 5 miles from Bath, a Drift of the Westleton character. It forms only a small patch on the otherwise bare surface of the Oolites, and consists of a light-brown sandy loam, with slightly subangular flints, some flint-pebbles, many white quartz-pebbles, and an occasional pebble of sandstone and of a greenish quartz *. It is covered by a brown earth with local Oolitic débris.

* The Rev. H. Winwood, F.G.S., has since found a subangular fragment of Sarsen stone and a pebble of black chert or hornstone.

The whole is only a few (5 to 8 feet) thick, and is preserved in a trough or hollow in the Oolite *.

Still further westward, on the Carboniferous-Limestone Hills near Clevedon, Mr. Trimmer † has recorded the existence of a patch of local débris with, I believe, quartz-pebbles, at a height of 300 feet above sea-level. This may be a continuation of the Kingsdown Bed, but intermediate connecting-links have yet to be discovered, and I was not successful in finding the place myself.

On the Chalk-hills to the south of the area we have described there are a few outliers which may be referable to this geological horizon, such, for instance, as the pebbly sands with worn fragments of hard Tertiary sandstones on Windmill Hill, near Alton, and a pebbly drift on the higher hills west of Andover; but these are too indistinct to pronounce definitely upon.

A better marked case is the one on the Chalk Downs of Copford, 8 miles east of Warminster, where a large Tertiary remnant has been preserved from denudation by having been let down into a cavity in the Chalk. This patch of Lower Tertiary (white sands and mottled clay) is overlain by an irregular spread of Drift consisting of:—

1. Tertiary flint-pebbles—the larger proportion much decomposed, white and very light.
2. White quartz-pebbles and a few rose-coloured ones.
3. Worn fragments of a light-coloured sandstone (Upper Greensand?).
4. Pebbles of a dark chert and Lydian stone.

These were imbedded in a light sandy matrix, and covered by a sandy clay-drift full of angular flints; this pit at the time of my visit was much obscured.

5. *The Relation of the Westleton Shingle to the Glacial Drifts of the Thames Valley.*

We have thus been able to follow the Westleton Beds from the coast of the Eastern Counties with some certainty as far as the Berkshire Downs, and with some probability as far as the Bristol Channel. On the Eastern coast this deposit lies at the sea-level, but as it ranges inland it gradually rises to heights of 500 or 600 feet. In the first instance the Westleton Beds underlie all the Glacial deposits; in the second they rise considerably above them, and their first seeming subordination to the Glacial series altogether disappears (see fig. 1, Pl. VII.).

The association, which is so close in Norfolk that it had led to the two series being considered members of the same group, becomes less so in Essex. At Braintree, where the Westleton Beds are largely developed, they stand up through the Boulder-clay and gravel which wrap round their base and partly surmount them.

* Mr. C. H. Weston, who first noticed this high-level drift, states also that Chalk-flints mixed with Oolitic débris occur on the surface of Farleigh Down at a height of about 600 feet (Quart. Journ. Geol. Soc. vol. vi. p. 449).

† Quart. Journ. Geol. Soc. vol. ix. p. 282 (1853).

They have there been disturbed and faulted (Pl. VII. fig. 6), before the intrusion of the Glacial Beds, which have deeply eroded them. As they rise to higher and more exposed levels, the Westleton Beds become greatly diminished in importance and are commonly reduced to a mere shingle-bed. On the hills near Epping, where they attain a height of 350 or 400 feet, they form a thin bed of sand and shingle, capping the London Clay, and quite apart from the Boulder-clay, which lies from 80 to 100 feet lower down on the slope of these hills at Theydon Bois and North Weald.

In Hertfordshire the distinction between the two deposits is very marked, as on the hills between Hoddesdon and Hatfield the Westleton Shingle forms a plateau-gravel high above the plain of the Lea, over which is spread the Boulder-clay with its associated sands and gravel. At Bell Bar and Mimms Wood the hills are also capped by this Shingle, while in the valley between them the Boulder-clay in the railway-cutting is at a level of from 100 to 150 feet lower. The Boulder-clay again enters the valley of the Colne at Bricket Wood and Aldenham, whilst Westleton Shingle lies on the neighbouring heights of Shenley and Bennett's End.

Here the Boulder-clay ends, and the Westleton Shingle alone is prolonged westward at intervals on the higher summits of the Buckinghamshire, Berkshire, and Oxfordshire Downs, the Chalk-plain on which these hills rise being in some places denuded, and at others thinly covered by Glacial Drift-beds. The Shingle-bed may, in this way, be traced to the northern edge of the Chalk Downs and to the extreme western end of the London Basin, which shows how extensive the submergence of these districts must have been at a time immediately antecedent to the Glacial period.

The height (500 to 600 feet) to which the Shingle-bed attains is sufficient to carry it over the summit of the Chalk and Oolitic hills of the Warminster and Bath districts. There may thus have been a Pre-Glacial sea bounded on the south by the Wealden anticlinal, and spreading northward over great part of Hertfordshire, Buckinghamshire, and Oxfordshire (and possibly beyond), while it stretched in the other direction from the North Sea to the Severn Basin or the Bristol Channel (see Part III. and Map).

6. *Origin of the Shingle.*

The distinctive features of the Westleton Shingle are of so marked a character and so different from those of the overlying Glacial series, that it is at once evident that their origin must be different. The characters of the latter are so well known that it is unnecessary to repeat them here; suffice it to say that they are essentially Drifts from the north and north-east, whereas that of the Westleton Beds is from the south and south-east, for the reason that the sources whence the several different component pebbles are derived is to be traced in those directions.

Thus:—1. The flint-pebbles are doubtlessly derived from the shingle-beds of Diestian, Bagshot, or Lower Tertiary (Woolwich)

age, whether in Belgium, the North of France, or Kent. 2. The Pebbles of white and rose-coloured quartz come apparently from the older rocks of the Ardennes or indirectly from some of the Bolderberg or Diestian beds of Belgium. 3. The subangular fragments of flint, some retaining their natural colour, others more worn and stained brown, are derived, the former directly from the Chalk, the latter from an older Drift, possibly of Pliocene age; or both may have been derived, in part, from the Southern Drift*. 4. The worn and subangular fragments of chert and ragstone are derived from the Lower Greensand of Kent and Surrey; or also, in part, possibly from the "Meule de Bracquegnies," or indirectly from the Southern Drift. 5. The Large Pebbles of a white or light-coloured quartzite and of a flat ovate shape, unlike the red or dark-coloured round ovoid quartzites from the Triassic conglomerates, may be derived indirectly from the shingle-beds of the Woolwich-and-Reading Series, where I have occasionally found them; or they may come from quartzites of the Palæozoic rock of the Ardennes, or possibly from both. 6. The small pebbles of Lydian stone, Jasper, veinstone, and worn fragments of old rocks may be derived, some directly from the Ardennes, and some indirectly from the pebbly beds of the Lower Greensand.

It is obvious, from the fossils found in it in Norfolk and Suffolk, that the Westleton Shingle is a marine Drift, the absence of shells in its inland range being no doubt in great measure owing to decalcification. Even in Suffolk, where the beds are more protected, it is rarely that anything more than casts are found.

But while marine conditions extended as far as the north of Belgium, on the south the Ardennes formed an elevated area of dry land, drained by the old Meuse and its tributaries as well as by the Schelde. The lower range of hills bordering these valleys above Spa and Liége are often capped by a terrace of gravel derived from the quartzose and schistose rocks, hard sandstones, and conglomerates of the Ardennes. Pebbles of quartzite, sandstone, and white quartz are consequently the common constituents of these gravels; while occasionally they contain fragments or pebbles of porphyry, slate, and, very rarely, of granite. Generally the pebbles vary in size from that of a marble to that of an egg, though they are sometimes the size of a man's head. Large blocks, but little rolled, are also occasionally met with.

Such was the old alluvium of the eastern tributaries of the Meuse, while on the terraces of the main stream at Dinant and Namur, pebbles of Triassic sandstones, of Cretaceous, Jurassic, Carboniferous, and Devonian rocks are met with, but a large proportion of them disappear lower down the course of the river, and only the harder rock-pebbles remain in its lower reaches. On the hill above Liége I noted in the flint-gravel palæozoic-rock pebbles very analogous to those found in the Westleton Shingle, namely:—

* To be described in Part III.

(Angular and subangular fragments of flint;)
White quartz-pebbles (numerous);
Flat ovate pebbles of light-coloured quartzites;
Pebbles of light-coloured sandstones, veinstone, and subangular fragments of a hard micaceous Sandstone, &c.,—

imbedded in a white and ochreous sandy matrix.

In descending the river the terraces become wider, and in the neighbourhood of Maestricht they spread out into plateau-sheets of great breadth, as in an estuary.

Another set of Drift-débris, including flint-pebbles from the Lower Tertiaries together with débris from the Carboniferous and Cretaceous strata, would be carried down by the Schelde, which flows through rocks of that age; while the Rhine may have furnished débris from the rocks of the Rhenish Provinces, including possibly the basalt of the Rhine borders.

This mass of shingle, transported into the open sea to the north and aided by ice-action, drifted over to the coast of Norfolk and Suffolk, and thence, as the land subsided, was carried westward, in a direction towards the Severn Valley or the Bristol Channel. What, then, turned it aside from the northern sea, where it would seem it might have extended more northward as the Crag did * at the period immediately antecedent? Could it have been that the great Scandinavian ice-sheet was then ploughing its way across the sea towards the coast of Norfolk, and so blocked up the sea in that direction and diverted the waters of the North Sea through this westward channel?

On the south, the spread of the Westleton Beds was limited by the anticlinal of the Ardennes and the Weald, which then constituted a low mountain-range, for there are no marine beds of that character south of the line I have described. At the same time palæontological evidence of contemporaneous land conditions is very scanty.

In recent papers by the Rev. O. Fisher † and Mr. J. C. Mansel-Pleydell, F.G.S. ‡, we have accounts of the discovery of the remains of *Elephas meridionalis* on the Chalk-plateau at Dewlish, near Piddletown, in Dorsetshire, in a bed of sand and gravel 90 feet above the level of the adjacent stream. The facts of the case led Mr. Fisher to suppose that the deposit might be Pre-Glacial, while Mr. Mansel-Pleydell considered it to be of Pliocene age.

It is possible also that the high-level fossiliferous Drift on the summit of Portland §, which contains débris derived from the Tertiary and Cretaceous strata of the hills to the north of Weymouth, may be of the same age, and older than I was first led to believe on the evidence of the sparse remains of *Elephas antiquus*, *E. primigenius*?, and *Equus fossilis*. This view of the greater antiquity of that deposit would be more in conformity with the enormous amount of erosion, probably of Glacial date, that led to the formation of

* Mr. T. F. Jamieson, F.G.S., has shown that Crag-beds exist on the east coast of Scotland (Quart. Journ. Geol. Soc. vol. xvi. p. 371).

† Quart. Journ. Geol. Soc. vol. xliv. p. 818 (1888).

‡ Trans. Dorset, vol. x. p. 12 (1889).

§ Quart. Journ. Geol. Soc. vol. xxxi. p. 31 (1875).

the broad valley between Portland and Upway, above six miles wide and from 400 to 500 feet deep, since the deposition of that high-level Drift.

Dr. Mourlon has also recently recorded * the occurrence, at Ixelles near Brussels, of a bed of sand and gravel with Mammalian remains, which he thinks may be of the age of the Forest-bed ; but the evidence is yet uncertain, owing to the fragmentary condition of the specimens. Amongst the species on which Dr. Mourlon relies, but which are determined with doubt, are *Elephas antiquus*, *Equus plicidens*, *Cervus canadensis*, and *Bison priscus*.

Conclusion.

It is clear from its uniformity and its marine origin that the Westleton Shingle must originally have formed a comparatively level sea-floor (or broad coast-line) throughout the area over which its outliers extend, and that all the inequalities of the surface below that level have been formed since it was deposited. If this conclusion be correct, then it follows that all the Tertiary strata, which spread originally over all the Chalk Downs of Hertfordshire, Buckinghamshire, Oxfordshire, Berkshire, Wiltshire, and some adjacent districts, have been removed subsequently to this early Pleistocene or so-called Pre-Glacial period; also that the gorge of the Thames at Pangbourne and Goring has been formed since then ; and that most of the Pre-Glacial valleys in the district, to which no date, except that they were Pre-Glacial, had been assigned, are of the same geological age. It follows further that before this date the Thames had no existence ; to this point we shall revert on another occasion.

During the Westleton period, we have to imagine a sea, with a coast-line extending from Belgium to the West of England, bounded on the south by the anticlinal range of the Wealden, and open to a yet uncertain distance to the north. This area then underwent an elevation from east to west, and from south to north, whereby it was raised at the extreme points from 500 to 600 feet or more above the sea-level, whereas it remained nearly at its original level and comparatively undisturbed at its other or eastern extremity ; so that while on the east the chronological orders of succession of the strata continued unbroken, to the west they became discordant, in consequence of the physiographical changes which intervened between these successive stages.

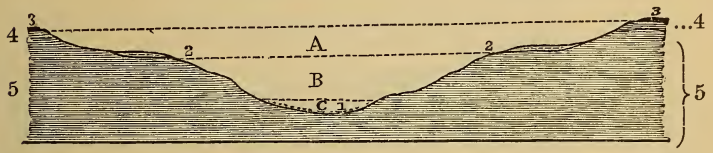
These changes and the action of meteorological agencies on the upraised land, determined the plotting-out of its hills and valleys during the early Glacial epoch. Of the first stage we have now, in some cases, an exact measure. Thus, to take a few examples, it is obvious that at the gorge of the Thames at Goring the Westleton Shingle and Tertiary Strata were continuous from side to side of the valley until the last elevation of the land. As they emerged, and a land-surface was formed, these beds, together with the underlying Chalk, were first denuded in the line of the present Thames valley

* Bull. Acad. Roy. Belgique, 3e sér. vol. xvii. p. 131 (1889).

to a depth of about 160 feet, and a width of from 2 to 4 miles, when the newly made channel received its covering of Northern Drift (2, fig. 13).

The successive increments of depth *, acquired during the different periods, are exhibited in the following section (see also fig. 12).

Fig. 13.—*Diagram-section across the Gorge of the Thames through the Escarpment of the Chalk at Goring.*



1. Post-Glacial Drift.
2. Glacial Drift.
3. Westleton Shingle.
4. Lower Tertiary strata.
5. Chalk.

		feet.
A. Denudation during the early Glacial Period	..... about	160
B. Denudation during the later Glacial Period	..... „	220
C. Denudation during the Post-Glacial Period	..... „	70

Taking the height above the sea-level of the Westleton Beds here at 600 feet, and that of the river at Goring at 150 feet, the above figures give, but very approximately, the depth to which the denudation of the valley at this place was carried during the successive Glacial and Post-Glacial epochs.

The relative depths of B and C may be subject to considerable correction. In the absence of sufficient evidence at Goring, I have been guided by the height of the high-level river-gravels at Oxford and Reading, where they are better developed.

These measures, of course, vary at different places. Lower down the Thames Valley, the channel A above Henley-on-Thames (Bowsey hill giving the Westleton level) is above 200 feet deep, while B is reduced in proportion.

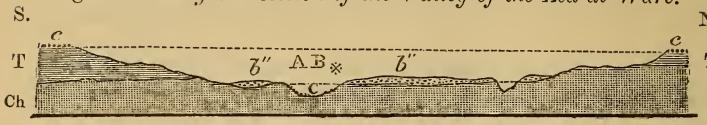
In the valley of the Lea, at Ware (fig. 14), taking the level of the Westleton Shingle at Hertford Heath on the south at 316 feet, and at Sacombe Green on the north at 362 feet, and that of the Lea at 110 feet, A and B together seem to amount, in round numbers, to about 200 feet, whilst C does not seem to exceed 50 feet.

In the valley of the Roding the level of the Boulder-clay is about 100 feet below that of the Westleton Shingle, at Jack's Hill, near Epping, whilst the extent of C is probably less than 30 feet.

Other instances might be mentioned, but these will suffice to show some of the stages in the denudation of this area and the initial step in the formation of its river-valleys. It will appear, from these facts, that the main denudation of the district has been effected after Pliocene times, and that the first stage (A) in the formation of the present gorge at Goring dates back to the time of

* These hold whatever may be the age of the shingle.

Fig. 14.—*Diagram-section of the Valley of the Lea at Ware.*



b″. Glacial sands and gravel with Boulder-clay at ※.
c. Westleton Shingle.
T. Lower Tertiaries and London Clay.
Ch. Chalk.

A B. Denudation during the Glacial Period.
C. Denudation during the Post-Glacial Period.

the emergence of the Westleton floor and is due to early Glacial action. To what extent the subsequent denudation (B) is due to continued glacial action it is difficult to say; but as the gravel-bed No. 2 (fig. 13) belongs to one of the earlier stages of the Glacial period, and Post-Glacial river-action (C) is limited to narrow bounds, there is reason to infer that the valley to about the base of B is due to erosion during the Glacial period.

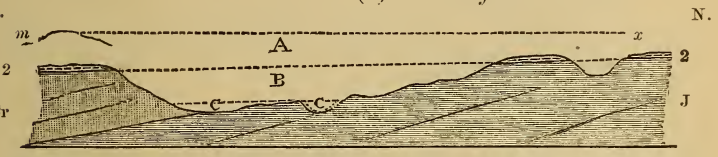
The position of the Westleton Shingle enables us also to suggest a solution of another question, namely, that relating to the age of the great escarpments of the Chalk and Oolites which run through the centre of England. The fact that the Westleton Shingle caps various Tertiary hills on the Chalk-plateau, which Tertiary strata extend to the edge of the Chalk-escarpment, renders it probable that this Shingle had, before the denudation of the Tertiary strata, a range to a certain extent coextensive with that of the Tertiary strata, and extending further northward than at present. This is manifested by the presence of the Shingle on an outlier so near the escarpment as Nettlebed Hill, and still more by the outlier on the very edge of the escarpment at Woodcote. Consequently, if, as this would show, the Westleton Beds had a range over and beyond the escarpment, the origin of that escarpment must be of a date subsequent to that of the Westleton Beds (Pl. VII. fig. 1).

Another argument is, I think, conclusive. The terraces of Glacial gravel (No. 2, fig. 13) which flank and originally spread across the gorge of the Thames at Goring at the height of 440 feet are evidently connected with the outliers capping the Coralline Oolite at Foxcombe and Wytham Hills near Oxford, at a height of about 500 feet, and which, again, cap the Forest Marble and Great Oolite on the higher hills of Wychwood Forest, near Witney. At the time that this spread of gravel took place, the intervening valleys must have been bridged over by a flooring of Cretaceous and Jurassic strata, which have been since removed and denuded to the depth of from 300 to 350 feet, as shown in the following diagram (fig. 15).

If, therefore, the channel through which the Glacial Drift passed from the north into the Thames Valley was formed, as we suppose, subsequently to the spread of the Westleton Shingle, but before the deeper late Glacial erosion, then it is evident that as the valley at the foot of and giving rise to the escarpment could

have had no existence at that time, the base of the escarpment must have been limited by the level of the line of 440 to 500 feet. By analogy the further relative heightening of the escarpment was concurrent with the deepening of the valley itself, which would correspond with B in fig. 15. In any case the escarpment could not

Fig. 15.—*Diagram-section from the Gorge of the Thames at Goring to the Oolitic hills* (J) *near Oxford.*



2. Glacial gravel with Triassic, Cretaceous, and other rock-débris. *m.* Position of Tertiary strata and of Westleton Shingle (outside the section). Cr. Cretaceous strata. J. Jurassic strata. (See also fig. 13, p. 149.)

at that early Glacial period (A) have had a face more than from 100 to 150 feet high, while at the Westleton period it is more than probable that it formed, with the distant Oolitic hills, a continuous plain (*x*).

Of the escarpment of the Oolites one can speak with less certainty, though if we admit the Kingsdown Drift outlier to be of Westleton age, it favours the conclusion that the escarpment of the Oolites dates no further back than the commencement of the Quaternary or Pleistocene period. The fact likewise that the two escarpments run in parallel lines seems in favour of a common denuding cause in the same direction. The time, geologically measured, is, however, so limited, and the extent of denudation so vast, that it is not easy to realize that these limits can suffice. Nevertheless, I do not see how the conclusions we have arrived at on this subject can well be avoided.

Another point to which I would draw attention is the small amount of erosion by river-action (C) in the area under review, compared with that effected by glacial or other agencies. To the latter are due the broad plains and passes and the isolated hills, whereas the effects of the former are limited to the valleys of comparatively moderate depth and width, which have been subsequently cut through the glaciated and deeply abraded land.

EXPLANATION OF PLATE VII. (see also Map, Pl. VIII.).

Diagram-sections of the Hill-Drifts of Pre-Glacial date in the Valley of the Thames within the Chalk-basin. Owing to the length of these sections and the limits of space the vertical scale is unavoidably exaggerated. In Fig. 1 it is not so important, as the gradients of the Westleton Shingle and Boulder-clay bear a tolerably uniform relation one to another; but in the other figures it misrepresents the incidence of level between the several Hill-Drifts, for which allowance must be made. The relative height of the hills and depth of the valleys are, however, on a true scale, and this is the essential point connected with the question. These are taken from the new 1-inch Ordnance Maps.

Fig. 1. Section from Oxfordshire to the coast of Suffolk. The length of this section is about 140 miles. The dotted lines prolong the levels of the Westleton Bed and Boulder-clay, and serve to indicate the extent of denudation which has taken place since each of these epochs respectively.

2. Section, about 50 miles long, passing from Hindhead through the Bagshot district and across the Valley of the Thames, near Windsor, to the borders of Hertfordshire.

3. Section from the edge of the Weald across the Norwood Hills, the Thames at London, and the Tertiary hills north of London, to the Valley of the Lea near Hatfield: distance about 40 miles.

4. Section from the Valley of the Medway, near Tunbridge, by Cobham, near Rochester, across South Essex to the Brentwood group of hills: distance about 36 miles.

Railway-Cuttings.

Fig. 5. Section of the Great Eastern Railway, through Brentwood Common. This cutting was of greater depth; only the upper 40 feet are represented in the figure. The surface is 360 feet above O.D.

A. Boulder-clay of a dark grey colour, containing fragments and small blocks of chalk, sandstone, Jurassic rocks, angular flints, and flint-pebbles, with a few specimens of *Gryphæa incurva* and a species of large Oyster. Eastward, it passes into a sandy bluish-green clay with flint-pebbles, and then into a brownish clay, roughly laminated and without pebbles. It has a maximum thickness of 30 feet.

A'. Sand and gravel, consisting chiefly of flint-pebbles. The sand contains thin subordinate layers of grey and brown clay.

D. Lower Bagshot Sands.

	feet.
1. Fine white sand passing into bed No. 2	10
2. Ochreous and ferruginous, sandy, with some iron-sandstone	4
3. The upper part of this bed consists of a tough brown laminated clay, with grains of green sand and a few patches of white micaceous sand, passing down into a massive argillaceous dark green sand, with some lighter seams. This bed contains numerous small *Lingulæ*, with casts of various bivalves in iron-pyrites, teeth, and vertebræ of Shark and *Carcharodon*, and fragments of wood pierced by *Teredo* ...	16 to 20
4. Fine light-yellowish sand, interstratified with thin irregular seams of laminated dark-grey clay. Traces of carbonaceous matter. No fossils. This bed varies in thickness, resting on an uneven surface of the London Clay	4 to 12

E. London Clay: dark grey with grains of green sand and concretions of iron-pyrites. Only traces of fossils.

Fig. 6. Section of the Black Notley Cutting on the branch line from Witham to Braintree. This fine and typical section was about half a mile in length, and about 25 feet deep in the centre.

A. Boulder-clay containing numerous large angular flints and chalk-pebbles; it passes from dark brown to a whitish colour.

A'. Boulder-clay gravel, very coarse and much contorted. It consists chiefly of subangular flints, pebbles of flint and white quartz, of dark quartzite and sandstones. The upper part is of a dull brownish-white colour, whilst the lower part is dashed with ochreous, ferruginous, and black seams and streaks, passing in places into a dark ferruginous conglomerate ..... 5 to 10 feet.

B. Fine sand and shingle, horizontally stratified, and in places obliquely laminated. It consists essentially of sand, with subordinate seams of shingle, composed of small flint- and white quartz-pebbles with some subangular flints. The upper half of this bed is ochreous, and coarser than the lower half, which is of a light yellow colour with faint ochreous seams. It is traversed by a few small faults of from 3 inches to 3 feet throw ..... 15 feet.

Fig. 7. Section between Chapple and Mark's Tey on the branch line to Sudbury.

A. Dark grey Boulder-clay, divided into an upper chalky and light-coloured bed, and a lower one of a dark bluish-brown colour. 14 feet.
B. Sand and gravel; the upper part coarse and ferruginous, the lower part white with ochreous seams and regularly stratified ..... 10 feet.
E. London Clay with seams of Septaria. This cutting is from 20 to 25 feet deep. At the time of my visit the central part was but just commenced, and is filled in from inference afforded by the trial-holes only.

Fig. 8. Section on the Railway at Kyson, one mile South of Woodbridge.
The Boulder-clay does not show in the Section, but crops out a little higher up the slope of the hill, above B.

a. Trail of loam and gravel.

		feet.
B. Westleton.	1. White sand, full of small flint- and white quartz-pebbles, subangular flints, chert, &c. (see p. 125)	2
	2. White and light yellow sand	1
C. Crag.	1. Bright yellow sand, with occasional oblique lamination, without fossils	10
	2. Coarse sand, much oblique lamination, shells in local patches	5
	3. Red Crag; very fossiliferous at the west end of the cutting, but fossils scarce at the east end. At the base is a thin bed of Coprolites, on a denuded floor of London-clay Septaria	12

E. London Clay.

Discussion.

The President said that a paper of this kind was the result of enormous observation and very careful reasoning. There was one point which had occurred to him: if the Westleton series were marine, either the whole area had been depressed uniformly, or there had been a greater depression to the westward. On the first hypothesis, thicker marine strata would probably have been found to the eastward and westward, and in the latter case it was remarkable that no marine beds of this age were found on the Western coast. He had no doubt that the Author had carefully considered the possibility of the subaerial origin of these beds before rejecting it.

Mr. Topley called attention to the section at Hertford Heath, and asked whether the composition of the beds was not peculiar. The evidence as to the southern origin of the pebbles he considered very important. If the older beds and the Westleton Beds are composed of Southern Drift, they are sharply marked off from the Glacial beds. A section exhibited from Hindhead to Windsor was of interest as bearing on the relation of these beds to the Chalk escarpment and the Weald. The escarpments might possibly be

older, and the Westleton Beds have lapped over them. Even if older than the escarpments, the beds were evidently newer than the elevation of the Weald.

Prof. Hughes pointed out the difficulty of correlating unfossiliferous and variable beds when they were separated by considerable intervals. He thought that movements along the Weald-axis and affecting all East Anglia had occurred many times down to a late age. The Glacial beds rest quite irregularly on the higher- and lower-level gravels of Hertfordshire. The Hertford-Heath beds had, he believed, nothing to do with the Glacial deposits, but that between them there had been an elevation, denudation, and resubmergence of that area, and that the ingredients of these beds might have come from the north and west. The pebbles became smaller, tracing the stones from Hertford Heath to Hampstead, where he recognized two Pebble-beds, the upper with quartz being the equivalent of the Hertford-Heath beds, and the lower being the Bagshot pebble-bed. He had traced them along the top of Epping Forest also, and would look for them on the North Downs. The Sheppey gravel was an angular one, and different from that of Hertford Heath; whilst there was a gravel near Chatham on the mainland opposite Sheppey of different origin, being the deposit of a stream flowing northwards from the Weald. He shared the general regret that the Author was unable to be present, especially as he could probably have cleared up some of these difficulties either by reference to parts of the paper which had not been read or by supplementary remarks.

Mr. J. Allen Brown had collected rocks from the high-level drifts of the Thames valley, and there was no doubt as to the occurrence of southern drift therein, though the northern drift preponderated.

Mr. Monckton agreed with the criticism of Prof. Hughes. There is a considerable break in the continuity of the proposed Westleton Beds north-east of High Beech, Essex.

The East-Berkshire plateau-gravels were shown in one of the diagrams; they were very different from the High-Beech gravels—quartz was, for instance, very rare in them, and he had placed on the table the only large block of quartz he had found in them.

Dr. Irving was sceptical as to the identification of the Berkshire gravels with those of Essex and Suffolk. The Author appeared, since his York paper, to have altered his views as to the date of the upheaval of the Weald. He was in accord with Prof. Prestwich as to a certain amount of glacial erosion, by which he meant the work done by floating ice. He believed that the plateau-gravels were themselves fluviatile and of much older date.

Mr. Marr stated that if the paper had been read in full many of the questions raised by the previous speakers would have been answered.